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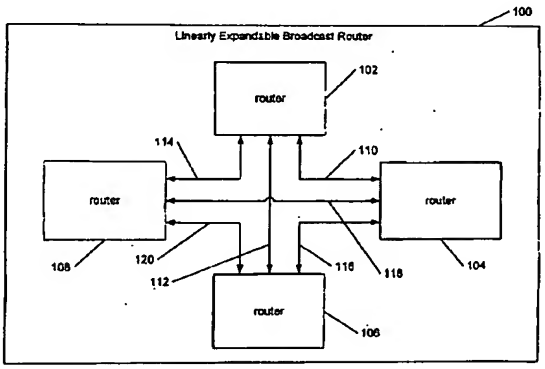

(57) Abstract: A linearly expandable router (100) is comprised of first, second, third and fourth router components (102, 104, 106 and 108). First, second and third discrete links (110, 112 and 114) couple an input side of a routing engine (128) of the first router component (102) to an input side of a routing engine (128) of the second, third and fourth router components (104, 106 and 108). Similarly, fourth and fifth discrete links (116 and 118) couple the input side of the routing engine (128) for the second router component (104) to the input side of the routing engine (128) of the third and fourth router components (106 and 108), respectively. Finally, a sixth discrete link (120) couples the input side of the routing engine (128) for the third router component (106) to the input side of the router engine (128) for the fourth router component (108).

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LINEARLY EXPANDABLE BROADCAST ROUTER APPARATUS

CROSS REFERENCE

This application is related to U.S. Provisional Patent Application Ser. No. 60/390,358 filed June 21, 2002.

This application is also related to co-pending U.S. Patent Application Ser. Nos. PCT/_____(Atty. Docket No. IU010620), PCT/_____ (Atty. Docket No. IU020157), PCT/_____(Atty. Docket No. IU020158), PCT/_____ (Atty. Docket No. IU020159), PCT/_____(Atty. Docket No. IU020160), PCT/_____ (Atty. Docket No. IU020161), PCT/_____(Atty. Docket No. IU020162), PCT/_____ (Atty. Docket No. IU020252), PCT/_____(Atty. Docket No. IU020253), PCT/_____ (Atty. Docket No. IU020254) and 10/_____(Atty. Docket No. IU020256), all of which were assigned to the Assignee of the present application and hereby incorporated by reference as if reproduced in their entirety.

FIELD OF THE INVENTION

The present invention relates to broadcast routers and, more particularly, to a linearly expandable broadcast router having plural routing engines arranged in a fully connected topology.

BACKGROUND OF THE INVENTION

A broadcast router allows each one of a plurality of outputs therefrom to be assigned the signal from any one of a plurality of inputs thereto. For example, an N x M broadcast router has N inputs and M outputs coupled together by a routing engine which allows any one of the N inputs to be applied to each one of the M outputs. Oftentimes, it is desirable to construct larger broadcast routers, for example a 4N x 4M broadcast router. One solution to building larger broadcast routers was to use the smaller broadcast router as a building block of the proposed larger broadcast router. This technique, however, resulted in the exponential growth of the proposed larger broadcast routers. For example, to construct a 4N x 4M broadcast router required 16 N x M broadcast routers. As a result, large broadcast routers

constructed in this manner were often both expensive and unwieldy. Linearly expandable broadcast routers overcame the problems of geometric expansion. However, conventionally configured linearly expandable broadcast routers suffer from other types of deficiencies. For example, oftentimes, they are susceptible to catastrophic failures which cause plural broadcast router components to fail in response to a single break.

SUMMARY OF THE INVENTION

A linearly expandable broadcast router is comprised of at least three routing engines, each having input and output sides, arranged in a fully connected topology. In the embodiment of the invention comprised of first, second and third routing engines, a first discrete link couples the input side of the first routing engine to the input side of the second routing engine. Similarly, a second discrete link couples the input side of the first routing engine to the input side of the third routing engine and a third discrete link couples the input side of the second routing engine to the input side of the third routing engine.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a block diagram of a linearly expandable broadcast router constructed in accordance with the teachings of the present invention;

FIG. 2 is an expanded block diagram of a first embodiment of the linearly expandable broadcast router of FIG. 1;

FIG. 3 is an expanded block diagram of an expansion port of a broadcast router component of the linearly expandable broadcast router of FIG. 2; and

FIG. 4 is an expanded block diagram of a second, alternate, embodiment of the linearly expandable broadcast router of FIG. 1.

DETAILED DESCRIPTION

Referring first to FIG. 1, a linearly expandable broadcast router 100 constructed in accordance with the teachings of the present invention will now be described in greater detail. As may now be seen, the linearly expandable broadcast router 100 is comprised of plural broadcast router components coupled to one another to form the larger linearly expandable broadcast router 100. Each broadcast router component is, of course, a discrete router having N inputs, M outputs and a routing engine, for example, switching logic, for selectively connecting any one of the M outputs to any one of the N inputs. As disclosed herein, each of the broadcast router components are N x M sized broadcast routers. However, it is fully

contemplated that the linearly expandable broadcast router 100 could instead be constructed of broadcast router components of different sizes relative to one another.

As further disclosed herein, the linearly expandable broadcast router 100 is formed by coupling together first, second, third and fourth broadcast router components 102, 104, 106 and 108. Of course, the present disclosure of the linearly expandable broadcast router 100 as being formed of four broadcast routers is purely by way of example. Accordingly, it should be clearly understood that a linearly expandable broadcast router constructed in accordance with the teachings of the present invention may be formed using various other numbers of broadcast router components as long as the total number of broadcast router components which collectively form the linearly expandable broadcast router is equal to or greater than three. The first, second, third and fourth broadcast router components 102, 104, 106 and 108 which, when interconnected in the manner disclosed herein, collectively form the linearly expandable broadcast router 100 may either be housed together in a common chassis as illustrated in FIG. 1 or, if desired, housed in separate chassis. While, as previously set forth, the broadcast router components 102, 104, 106 and 108 may have different sizes relative to one another or, in the alternative, may all have the same N x M size, one size that has proven suitable for the uses contemplated herein is 256 x 256. Furthermore, a suitable configuration for the linear expandable broadcast router 100 would be to couple five broadcast router components, each sized at 256 x 256, thereby resulting in a 1,280 x 1,280 broadcast router.

The first, second, third and fourth broadcast router components 102, 104, 106 and 108 of the linearly expandable broadcast router 100 are coupled together in a fully connected topology. When the broadcast router components of a linearly expandable broadcast router are arranged in a fully connected topology, each broadcast router component is connected to each and every one of the other broadcast router components by a discrete link. In other words, first, second and third bi-directional links 110, 112 and 114 couples the first broadcast router component 102 to the second, third and fourth broadcast router components 104, 106 and 108, respectively. Additionally, fourth and fifth bi-directional links 116 and 118 couple the second broadcast router component 104 to the third and fourth broadcast router components 106 and 108, respectively. Finally, a sixth bi-directional link 120 couples the third broadcast router component 106 to the fourth broadcast router component 108. Variously, the bi-directional links 110 through 120 may be formed of copper wire, optical fiber or another transmission medium deemed suitable for the exchange of digital signals. Of

course, rather than the single bi-directional links between pairs of broadcast router components illustrated in FIG. 1, in an alternate embodiment of the invention, it is contemplated that the pairs of broadcast router components may instead be coupled together by first and second uni-directional links. Such an alternate configuration is illustrated in FIG. 2.

Turning now to FIG. 2, the linearly expandable broadcast router 100 will now be described in greater detail. As may now be seen, each one of the first, second, third and fourth broadcast router components 102, 104, 106 and 108 has N selectors 122-1 through 122-N arranged such that the output of each one of the selectors provides one of the N inputs to the input side of the routing engine for that broadcast router component 102, 104, 106, 108. As disclosed herein, each one of the selectors 122-1 through 122-N is a 2:1 selector circuit having, as a first input 124-1 through 124-N, respectively, an input digital audio data stream conforming to the Audio Engineering Society-3 ("AES-3") standard and, as a second input 126-1 through 126-N, respectively, an input digital audio data stream conforming to the multichannel digital audio interface ("MADI") standard set forth in the AES-10 standard. In this regard, it should be noted that a MADI input digital audio data stream may contain up to 32 AES digital audio data streams and that, each one of the second inputs 126-1 through 126-N contains a single AES digital audio data stream which had previously been extracted from a MADI input digital audio data stream by extraction circuitry (not shown). Thus, the output of each one of the selector circuits 122-1 through 122-N provides one of N input digital audio data streams to the input side of the routing engine for that broadcast router component 102, 104, 106, 108. Each one of the selector circuits 122-1 through 122-N further includes a control input (not shown) for selecting between the AES input digital audio data streams provided at the first inputs 124-1 through 124-N and MADI-extracted AES input digital audio data streams provided at the second inputs 126-1 through 126-N. Of course, it should be readily appreciated that other types of input data streams other than the input digital audio data streams disclosed herein are equally suitable for use with the broadcast router components 102, 104, 106 and 108. For example, it is contemplated that the broadcast router components 102, 104, 106 and 108 may instead be used with other low bandwidth digital signals such as compressed video and data signals. It is further contemplated that, with minor modifications, for example, faster hardware, the broadcast router components 102, 104, 106 and 108 may be used with non-compressed digital video signals.

For each of the first, second, third and fourth broadcast router components 102, 104, 106 and 108, the selected input digital audio data stream output each one of the selector circuits 122-1 through 122-N is fed to an input side of a routing engine 128, a first expansion port 130, a second expansion port 132 and a third expansion port 134. Residing within the routing engine 128 is switching means for assigning any one of the input digital audio data signals received on the input side of the routing engine 128 to any one of the output lines on an output side of the routing engine 128. Variously, it is contemplated that the routing engine 128 may be embodied in software, for example, as a series of instructions; hardware, for example, as a series of logic circuits; or a combination thereof. In a broad sense, each one of the first, second and third expansion ports 130, 132 and 134 is comprised of a memory subsystem in which: (1) input digital audio data streams received from the selector circuits 122-1 through 122-N of a first broadcast router component; and (2) input digital audio data streams received from an expansion port of a second broadcast router component may be buffered before transfer to their final destination and a processor subsystem for controlling: (1) the transfer of the input digital audio data streams received from the selector circuits 122-1 through 122-N to the expansion port of the second broadcast router component; and (2) the transfer of the input digital audio data streams received from the expansion port of the second broadcast router component to the input side of the routing engine 128 of the first broadcast router component.

Turning momentarily to FIG. 3, the first, second and third expansion ports 130, 132 and 134 will now be described in greater detail. In this regard, it should be noted that, while, the first expansion ports 130 of the first broadcast router component 102 is described and illustrated herein, as the second and third expansion ports 132 and 134 of the first broadcast router component and the first, second and third expansion ports 130, 132 and 134 of the second, third and fourth broadcast router components 104, 106 and 108 are similarly configured, the description that follows is equally applicable to those expansion ports as well. Accordingly, as may be seen in FIG. 3, the first expansion port 130 includes a first memory space 142 and a second memory space 144. Variously, the first and second memory spaces 142 and 144 may be comprised of first and second discrete memory devices or, as shown in FIG. 3, may be comprised of first and second discrete address spaces within a common memory device.

The expansion port 130 further includes control circuitry 146, for example, a controller, for controlling the transfer of input digital audio data streams, received by the expansion port 130, to their final destinations. More specifically, the input digital audio data stream output the selector circuit coupled to the expansion port 130, for example, the selector circuit 130-1, is temporarily stored, or buffered, in the first memory space 142. The controller 146 then transfers the digital audio data stored in the first memory space 142 to the second memory space 144 of the expansion port 130 of the second broadcast router component 104. Similarly, the digital audio data stored in the first memory space 142 of the expansion port 130 of the second broadcast router component 104 is transferred to the second memory space 144. From the second memory space 144, the controller 146 transfers the digital audio data received from the second broadcast router component 104 to the input side of the routing engine 128 for the first broadcast router component 102. Of course, the configuration and operation of the expansion port 130 are but one device and associated process suitable for the transfer of digital audio data and it is fully contemplated that other devices and/or processes involving buffering and/or first-in-first-out ("FIFO") schemes are equally suitable for the purposes disclosed herein.

As a discrete input digital audio data stream is output each of the selectors 122-1 through 122-N for each of the first, second, third and fourth broadcast router components 102, 104, 106 and 108, the input digital audio data streams fed to each one of the input side of the routing engine 128, the first expansion port 130, the second expansion port 132 and the third expansion port 134 of the first broadcast router component 102 are audio data input streams 1 through N. Similarly, the input digital audio data streams fed to each one of the input side of the routing engine 128, the first expansion port 130, the second expansion port 132 and the third expansion port 134 of the second broadcast router component 104 are input digital audio data streams N+1 through 2N; the input digital audio data streams fed to each one of the input side of the routing engine 128, the first expansion port 130, the second expansion port 132 and the third expansion port 134 of the third broadcast router component 106 are input digital audio data streams 2N+1 through 3N; and the input digital audio data streams fed to each one of the input side of the routing engine 128, the first expansion port 130, the second expansion port 132 and the third expansion port 134 of the fourth broadcast router component 108 are input digital audio data streams 3N+1 through 4N.

To function as a 4N x 4M broadcast router, the routing engine 128 of each one of the first, second, third and fourth broadcast router components 102, 104, 106 and 108 must have all of the input digital audio data streams 1 through 4N provided as inputs to the input side thereof. For the first broadcast router component 102, the input digital audio data streams 1 through N are provided to the input side of the routing engine 128 directly. The input digital audio data streams 1 through N input the expansion ports 130, 132 and 134, on the other hand, are transferred to the expansion port 130 of the second broadcast router component 104 over the link 110, the expansion port 132 of the third broadcast router component 106 over the link 112 and the expansion port 130 of the fourth broadcast router component 108 over the link 114, respectively. From the expansion port 130 of the second broadcast router component 104, the expansion port 132 of the third broadcast router component 106 and the expansion port 130 of the fourth broadcast router component 108, the input digital audio data streams 1 through N are transferred to the input side of the routing engines 128 of the second, third and fourth broadcast router components 104, 106 and 108, respectively.

Similarly, for the second broadcast router component 104, the input digital audio data streams N+1 through 2N are provided to the input side of the routing engine 128 directly. The input digital audio data streams N+1 through 2N input the expansion ports 130, 132 and 134, on the other hand, are transferred to the expansion port 130 of the first broadcast router component 102 over the link 110, the expansion port 132 of the fourth broadcast router component 108 over the link 118 and the expansion port 130 of the third broadcast router component 106 over the link 116, respectively. From the expansion port 130 of the first broadcast router component 102, the expansion port 132 of the fourth broadcast router component 108 and the expansion port 130 of the third broadcast router component 106, the input digital audio data streams N+1 through 2N are transferred to the input side of the routing engines 128 of the first, fourth and third broadcast router components 104, 108 and 106.

For the third broadcast router component 106, the input digital audio data streams 2N+1 through 3N are provided to the input side of the routing engine 128 directly. The input digital audio data streams 2N+1 through 3N input the expansion ports 130, 132 and 134, on the other hand, are transferred to the expansion port 134 of the second broadcast router component 104 over the link 116, the expansion port 132 of the first broadcast router component 102 over the link 112 and the expansion port 134 of the fourth broadcast router component 108 over the link 120, respectively. From the expansion port 134 of the second

broadcast router component 104, the expansion port 132 of the first broadcast router component 102 and the expansion port 134 of the fourth broadcast router component 108, the input digital audio data streams 2N+1 through 3N are transferred to the input side of the routing engines 128 of the second, first and fourth broadcast router components 104, 102 and 108.

Finally, for the fourth broadcast router component 108, the input digital audio data streams 3N+1 through 4N are provided to the input side of the routing engine 128 directly. The input digital audio data streams 3N+1 through 4N input the expansion ports 130, 132 and 134, on the other hand, are transferred to the expansion port 134 of the first broadcast router component 102 over the link 114, the expansion port 132 of the second broadcast router component 104 over the link 118 and the expansion port 134 of the fourth broadcast router component 108 over the link 120, respectively. From the expansion port 134 of the first broadcast router component 102, the expansion port 132 of the second broadcast router component 104 and the expansion port 134 of the fourth broadcast router component 108, the input digital audio data streams 3N+1 through 4N are transferred to the input side of the routing engines 128 of the first, second and fourth broadcast router components 102, 104 and 108. In this manner, the routing engine 128 of each one of the first, second, third and fourth broadcast router components 102, 104, 106 and 108 receive, at the input side thereof, the input digital audio data streams 1 through 4N.

Within the routing engine 128 of the first broadcast router component 102, switch logic or other switching means enables any one of the input digital audio data streams 1 through 4n to be applied to any of the 1 through m outputs thereof. Similarly, switch logic or other switching means within the routing engine 128 of the second, third and fourth router components 104, 106 and 108 enables any one of the input digital audio data streams 1 through 4N to be applied to any of the M+1 through 2M, 2M+1 through 3M and 3M+1 through 4M outputs thereof, respectively. The switching logic or other switching means within the routing engines 128 is controlled by one or more control inputs which originate at a controller (not shown) or other control circuitry for the linearly expandable broadcast router 100.

Each one of the 1 through M, M+1 through 2M, 2M+1 through 3M and 3M+1 through 4M digital audio data streams output the output side of the routing engines 128 of the first, second, third and fourth broadcast router components 102, 104, 106 and 108, respectively, is

propagated to a corresponding selector 136-1 through 136-M. As disclosed herein, each one of the selectors 136-1 through 136-M is a 1:2 selector circuit having an input coupled to a corresponding output of the routing engine 128, a first output 138-1 through 138-M configured to transmit an output digital audio data stream conforming to the AES-3 standard and a second output 140-1 through 140-M configured to transmit an output digital audio data stream conforming to the MADI standard. Of course, since, as previously mentioned, a MADI input digital audio data stream may contain up to 32 AES digital audio data streams, each one of the second outputs 140-1 through 140-M would actually contain a single AES digital audio stream which would then be combined with other AES digital audio streams by combining circuitry (not shown) to form a MADI output digital audio data stream. Each one of the selector circuits 136-1 through 136-M further includes a control input (also not shown) for selecting between the AES-3 and MADI output digital audio data streams.

In an alternate embodiment of the invention not shown in the drawings, the selector circuits 122-1 through 122-N and 136-1 through 136-M may be omitted if the broadcast router components 102, 104, 106 and 108 are instead configured to handle input digital audio data streams conforming to a single standard, for example, the AES-3 standard, the MADI standard or another standard not specifically recited herein. In accordance with this configuration, however, each of the N input digital audio data streams for each of the first, second, third and fourth broadcast router components 102, 104, 106 and 108 are fed directly to the routing engine 128, first expansion port 130, second expansion port 132 and third expansion port 134. In further accordance with this configuration, each of the M output digital audio data streams output the routing engine 128 for each of the first, second, third and fourth broadcast router components 102, 104, 106 and 108 are outputs of the linearly expandable broadcast router 100 itself.

Referring next to FIG. 4, an alternate embodiment of the linearly expandable broadcast router 100 will now be described in greater detail. As may now be seen, for each of the first, second, third and fourth broadcast router components 102, 104, 106 and 108, the first expansion port 130, the second expansion port 132 and the third expansion port 134 have been removed in favor of a transmitting ("TX") expansion port 148, a first receiving expansion port 150, a second receiving expansion port 152 and a third receiving expansion port 154. By the term "transmitting" expansion port, it is intended to refer to an expansion port from which data is transmitted to selected destinations, here, plural receiving expansion port. Similarly,

by the term "receiving" expansion port, it is intended to refer to an expansion port which receives data from a transmitting expansion port. In a broad sense, each transmitting expansion port 148 of a given broadcast router component is comprised of a memory subsystem in which input digital audio data streams received from the selector circuits 122-1 through 122-N are buffered before transfer to plural destinations and a processor subsystem for controlling the transfer of the input digital audio data streams received from the selector circuits 122-1 through 122-N to a receiving expansion port of each of the other broadcast router components. Conversely, each one of the first, second and third receiving expansion ports 150, 152 and 154 of a given broadcast router component are, in a broad sense, comprised of a memory subsystem in which input digital audio data streams received from a transmitting expansion port of another broadcast router component are buffered before transfer to their destination and a processor subsystem for controlling the transfer of the input digital audio data streams received from the transmitting expansion port of the other broadcast router component to inputs of the routing engine of the broadcast router component.

For each of the first, second, third and fourth broadcast router components 102, 104, 106 and 108, the selected input digital audio data stream output each one of the selector circuits 122-1 through 122-N is fed to the input side of the routing engine 128 and to the transmission expansion port 148. As a discrete input digital audio data stream is output each of the selectors 122-1 through 122-N for each of the first, second, third and fourth broadcast router components 102, 104, 106 and 108, the input digital audio data streams fed to each one of the input side of the routing engine 128 and the transmission expansion port 148 of the first broadcast router component 102 are audio data input streams 1 through N. Similarly, the input digital audio data streams fed to each one of the input side of the routing engine 128 and the transmission expansion port 148 of the second broadcast router component 104 are input digital audio data streams N+1 through 2N; the input digital audio data streams fed to each one of the input side of the routing engine 128 and the transmission expansion port 148 of the third broadcast router component 106 are input digital audio data streams 2N+1 through 3N; and the input digital audio data streams fed to each one of the input side of the routing engine 128 and the transmission expansion port 148 of the fourth broadcast router component 108 are input digital audio data streams 3N+1 through 4N.

As before, to function as a 4N x 4M broadcast router, the routing engine 128 of each one of the first, second, third and fourth broadcast router components 102, 104, 106 and 108

must have all of the input digital audio data streams 1 through 4N provided as inputs to the input side thereof. For the first broadcast router component 102, the input digital audio data streams 1 through N are provided to the input side of the routing engine 128 directly. The input digital audio data streams 1 through N input the transmission expansion ports 148, on the other hand, is transferred to the first receiving expansion port 150 of the second broadcast router component 104 over the link 110, the second receiving expansion port 152 of the third broadcast router component 106 over the link 112 and the first receiving expansion port 150 of the fourth broadcast router component 108 over the link 114, respectively. From the first receiving expansion port 150 of the second broadcast router component 104, the second receiving expansion port 152 of the third broadcast router component 106 and the first receiving expansion port 150 of the fourth broadcast router component 108, the input digital audio data streams 1 through N are transferred to the input side of the routing engines 128 of the second, third and fourth broadcast router components 104, 106 and 108, respectively.

Similarly, for the second broadcast router component 104, the input digital audio data streams N+1 through 2N are provided to the input side of the routing engine 128 directly. The input digital audio data streams N+1 through 2N input the transmission expansion port 148, on the other hand, is transferred to the first receiving expansion port 150 of the first broadcast router component 102 over the link 110, the first expansion port 150 of the third broadcast router component 106 over the link 116 and the second receiving expansion port 152 of the third broadcast router component 106 over the link 118, respectively. From the first receiving expansion port 150 of the second broadcast router component 104, the first receiving expansion port 150 of the third broadcast router component 106 and the second receiving expansion port 152 of the fourth broadcast router component 108, the input digital audio data streams N+1 through 2N are transferred to the input side of the routing engines 128 of the second, third and fourth broadcast router components 104, 106 and 108.

For the third broadcast router component 106, the input digital audio data streams 2N+1 through 3N are provided to the input side of the routing engine 128 directly. The input digital audio data streams 2N+1 through 3N input the transmission expansion port 148, on the other hand, are transferred to the second receiving expansion port 152 of the first broadcast router component 102 over the link 112, the third receiving expansion port 154 of the second broadcast router component 104 over the link 116 and the third receiving expansion port 154 of the fourth broadcast router component 108 over the link 120, respectively. From the

second receiving expansion port 152 of the first broadcast router component 102, the third receiving expansion port 154 of the second broadcast router component 104 and the third receiving expansion port 154 of the fourth broadcast router component 108, the input digital audio data streams 2N+1 through 3N are transferred to the input side of the routing engines 128 of the first, second and fourth broadcast router components 102, 104 and 108.

Finally, for the fourth broadcast router component 108, the input digital audio data streams 3N+1 through 4N are provided to the input side of the routing engine 128 directly. The input digital audio data streams 3N+1 through 4N input the transmission expansion port 148, on the other hand, is transferred to the third receiving expansion port 154 of the first broadcast router component 102 over the link 114, the second receiving expansion port 152 of the second broadcast router component 104 over the link 118 and the third receiving expansion port 154 of the third broadcast router component 108 over the link 120, respectively. From the third receiving expansion port 154 of the first broadcast router component 102, the second receiving expansion port 152 of the second broadcast router component 104 and the third receiving expansion port 154 of the fourth broadcast router component 108, the input digital audio data streams 3N+1 through 4N are transferred to the input side of the routing engines 128 of the first, second and fourth broadcast router components 102, 104 and 108. In this manner, the routing engine 128 of each one of the first, second, third and fourth broadcast router components 102, 104, 106 and 108 receive, at the input side thereof, the input digital audio data streams 1 through 4N. Further processing of the input digital audio streams 1 through 4N by the first, second, third and fourth broadcast router components 102, 104, 106 and 108 will then proceed in the manner hereinabove described with respect to FIG. 2.

Thus, there has been disclosed and illustrated herein a robust linearly expandable broadcast router which, by employing a fully connected topology between the plural broadcast router components forming the linearly expandable broadcast router, enjoys improved fault tolerance over prior linearly expandable broadcast routers using plural bus structures to interconnect the plural broadcast router components. While preferred embodiments of this invention have been shown and described herein, various modifications and other changes can be made by one skilled in the art to which the invention pertains without departing from the spirit or teaching of this invention. Accordingly, the scope of protection is not limited to the embodiments described herein, but is only limited by the claims that follow.

CLAIMS

1. A linearly expandable router (100), comprising:

a first routing engine (128) having input and output sides;

a second routing engine (128) having input and output sides;

a third routing engine (128) having input and output sides;

a first link (110), said first link (110) coupling said input side of said first routing engine (128) to said input side of said second routing engine (128);

a second link (112), said second link (112) coupling said input side of said first routing engine (128) to said input side of said third routing engine (128); and

a third link (116), said third link (116) coupling said input side of said second routing engine (128) to said input side of said third routing engine (128);

wherein said first, second and third routing engines (128) are arranged in a fully connected topology.

2. The apparatus of claim 1, wherein:

said first, second and third routing engines (128) each have N inputs to said input side thereof and M outputs from said output side thereof; and

said linearly expandable router (100) formed from said first, second and third routing engines (128) having 3N inputs and 3M outputs.

3. The apparatus of claim 2, wherein:

said first link (110) providing said N inputs to said first routing engine (128) to said input side of said second routing engine (128) as a first N additional inputs thereto and providing said N inputs to said second routing engine (128) to said input side of said first routing engine (128) as a first N additional inputs thereto;

said second link (112) providing said N inputs to said first routing engine (128) to said input side of said third routing engine (128) as a first N additional inputs thereto and providing said N inputs to said third routing engine (128) to said input side of said first routing engine (128) as a second N additional inputs thereto; and

said third link (116) providing said N inputs to said second routing engine (128) to said input side of said third routing engine (128) as a second N additional

inputs thereto and providing said N inputs to said third routing engine (128) to said input side of said second routing engine (128) as a second N additional inputs thereto.

4. The apparatus of claim 1, and further comprising:

a fourth routing engine (128) having input and output sides;

a fourth link (114), said fourth link (114) coupling said input side of said first routing engine (128) to said input side of said fourth routing engine (128);

a fifth link (118), said fifth link (118) coupling said input side of said second routing engine (128) to said input side of said fourth routing engine (128); and

a sixth link (120), said sixth link (120) coupling said input side of said third routing engine (128) to said input side of said fourth routing engine (128);

wherein said first, second, third and fourth routing engines (128) are arranged in a fully connected topology.

5. The apparatus of claim 4, wherein:

said first, second, third and fourth routing engines (128) have N inputs to said input side and m outputs from said output side; and

said linearly expandable router (100) formed from said first, second, third and fourth routing engines (128) having 4N inputs and 4M outputs.

6. The apparatus of claim 5, wherein:

said first link (110) providing said N inputs to said first routing engine (128) to said input side of said second routing engine (128) as a first N additional inputs thereto and providing said N inputs to said second routing engine (128) to said input side of said first routing engine (128) as a first N additional inputs thereto;

said second link (112) providing said N inputs to said first routing engine (128) to said input side of said third routing engine (128) as a first N additional inputs thereto and providing said N inputs to said third routing engine (128) to said input side of said first routing engine (128) as a second N additional inputs thereto;

said third link (114) providing said N inputs to said first routing engine (128) to said input side of said fourth routing engine (128) as a first N additional

inputs thereto and providing said N inputs to said fourth routing engine (128) to said input side of said first routing engine (128) as a third N additional inputs thereto;

said fourth link (116) proving said N inputs to said second routing engine (128) to said input side of said third routing engine (128) as a second N additional inputs thereto and providing said N inputs to said third routing engine (128) to said input side of said second routing engine (128) as a second N additional inputs thereto;

said fifth link (118) proving said N inputs to said second routing engine (128) to said input side of said fourth routing engine (128) as a second N additional inputs thereto and providing said N inputs to said fourth routing engine (128) to said input side of said second routing engine (128) as a third N additional inputs thereto;

said sixth link (120) proving said N inputs to said third routing engine (128) to said input side of said fourth routing engine (128) as a third N additional inputs thereto and providing said N inputs to said fourth routing engine (128) to said input side of said third routing engine (128) as a third N additional inputs thereto.

7. A linearly expandable broadcast router (100), comprising:

at least three broadcast router components (102, 104, 106), each of said at least three broadcast router components (102, 104, 106) having an input side and an output side; and

means (110, 112, 116) for coupling said at least three linear expandable broadcast router components (102, 104, 106) in a fully interconnected topology.

8. The apparatus of claim 7, wherein said input side of each of said at least three broadcast router components (102, 104, 106) has N inputs and said output side of each of said at least three broadcast router components (102, 104, 106) has M outputs.

9. The apparatus of claim 8, wherein:

each one of said at least three broadcast router components (102, 104, 106) further comprises a routing engine (128) coupled between said input and output sides thereof; and

said coupling means (110, 112, 116) further comprises means for coupling (130, 132 130) said N inputs for each one of said at least three broadcast router components (102, 104, 106) to said routing engine (128) for the other ones of said at least three broadcast router components.

10. A method of constructing a linearly expandable broadcast router (100), comprising:

providing first, second and third routers (102, 104, 106), each having input and output sides;

coupling, using a first discrete path (110), said input side of said first router (102) to said input side of said second router (104);

coupling, using a second discrete path (112), said input side of said first router (102) to said input side of said third router (106); and

coupling, using a third discrete path (116), said input side of said second router (104) to said input side of said third router (106).

11. The method of claim 10, and further comprising:

providing a fourth router (108) having input and output sides;

coupling, using a fourth discrete path (114), said input side of said first router (102) to said input side of said fourth router (108);

coupling, using a fifth discrete path (118), said input side of said second router (104) to said input side of said fourth router (108); and

coupling, using a sixth discrete path (120), said input side of said third router (106) to said input side of said fourth router (108).

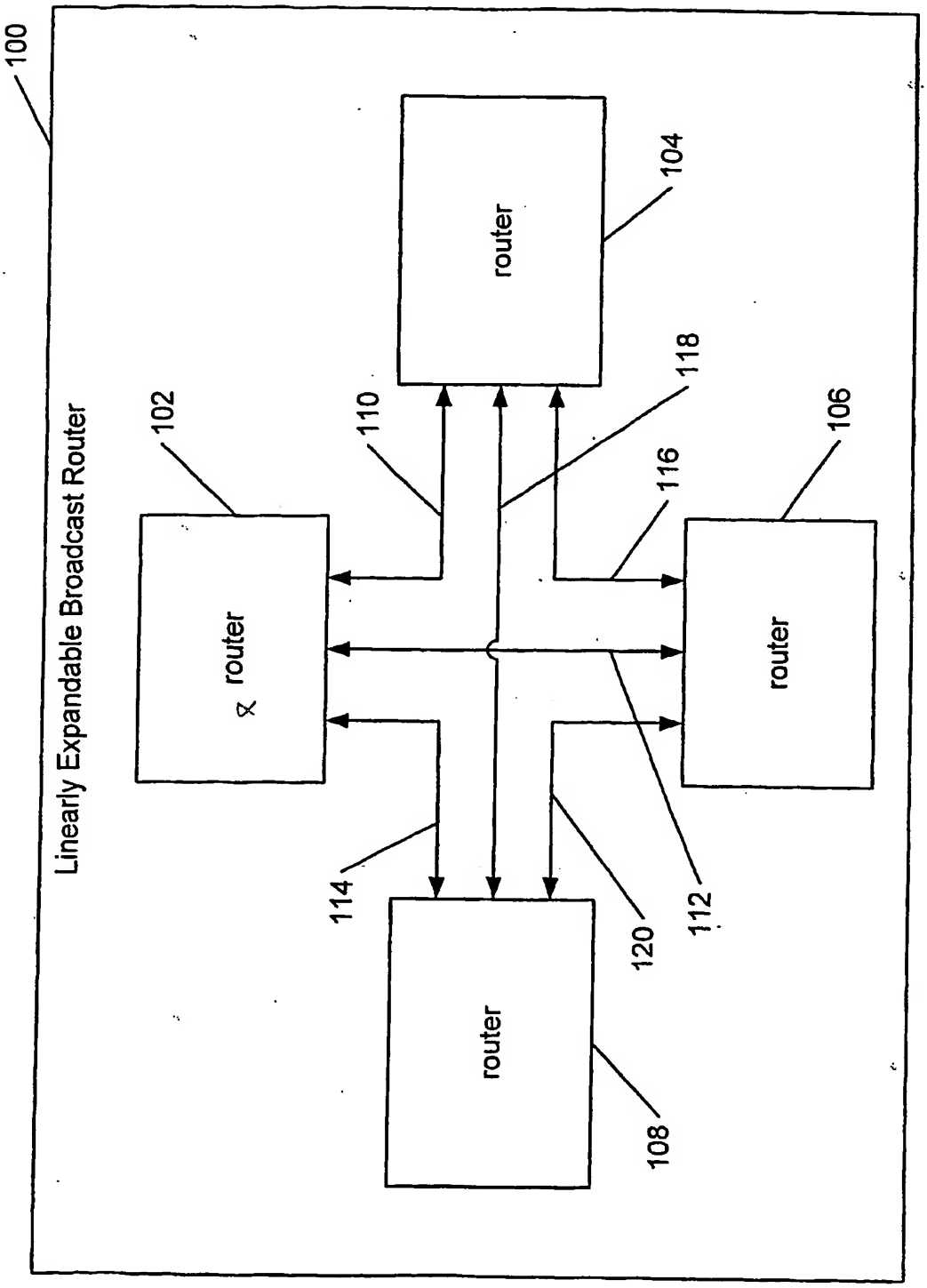
100
Linearly Expandable Broadcast Router
router
104
118
102
110
106
116
router
router
114
120
112
router
108

FIG. 1

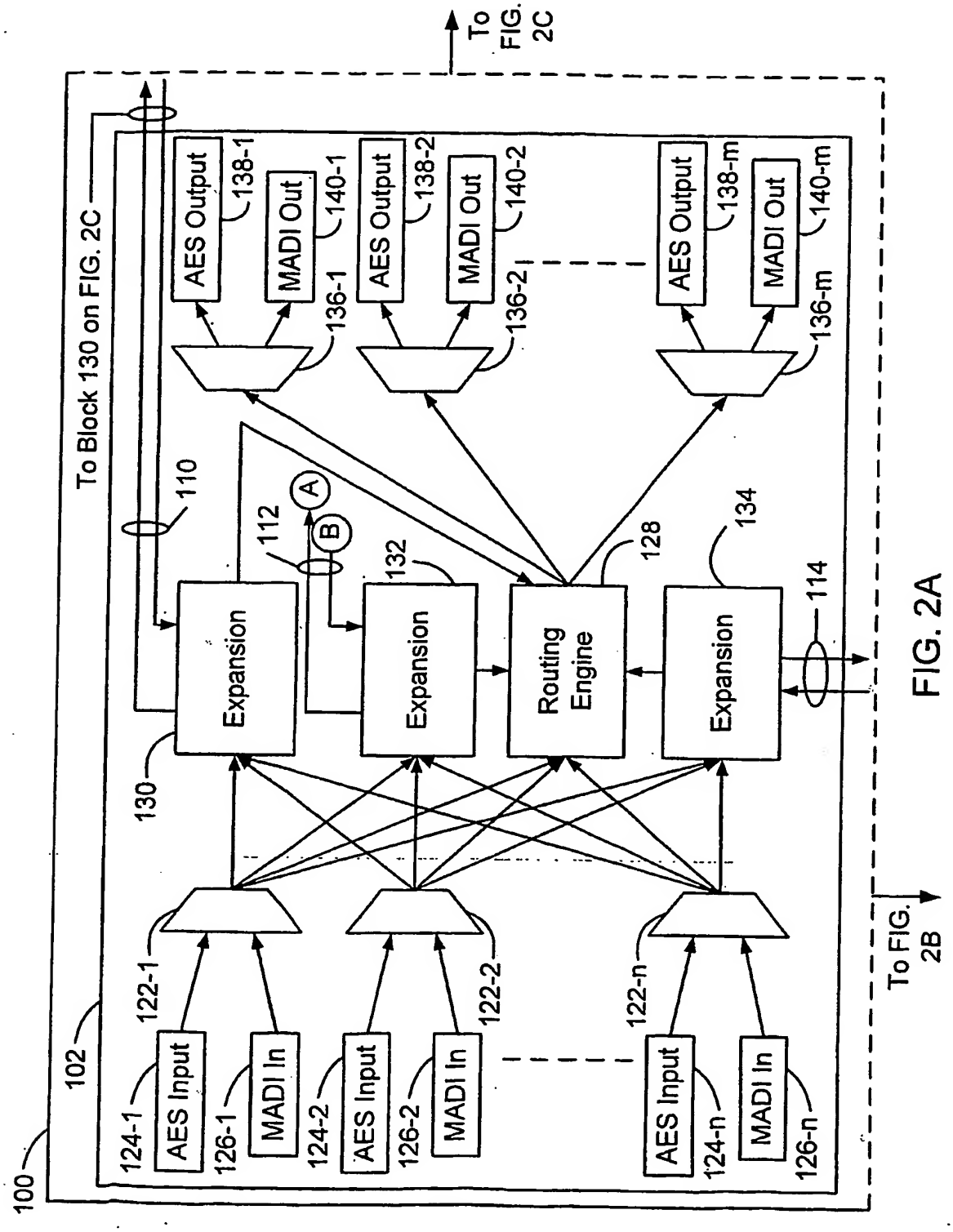
To FIG. 2C
To Block 130 on FIG. 2C
AES Output
138-1
MADI Out
140-1
136-1
AES Output
138-2
MADI Out
140-2
136-2
AES Output
138-m
MADI Out
140-m
136-m
110
112
A
B
132
128
134
114
Expansion
Expansion
Routing Engine
Expansion
130
122-1
122-2
122-n
AES Input
124-1
MADI In
126-1
AES Input
124-2
MADI In
126-2
AES Input
124-n
MADI In
126-n
102
100
To FIG. 2B

FIG. 2A

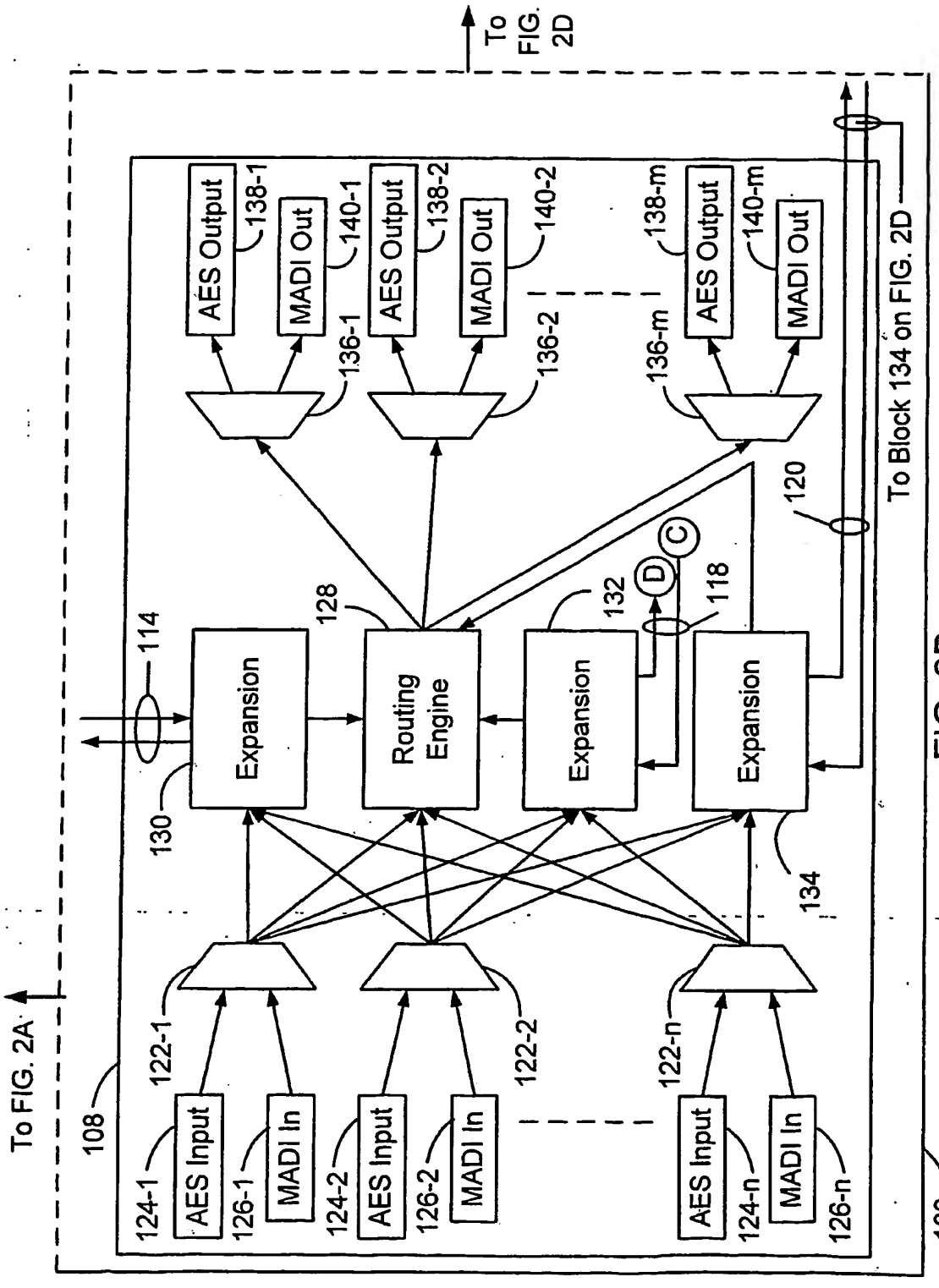
To FIG. 2D
To Block 134 on FIG. 2D
To FIG. 2A
AES Output
MADI Out
AES Input
MADI In
Expansion
Routing Engine
100
108
114
118
120
122-1
122-2
122-n
124-1
124-2
124-n
126-1
126-2
126-n
128
130
132
134
136-1
136-2
136-m
138-1
138-2
138-m
140-1
140-2
140-m
C
D

FIG. 2B

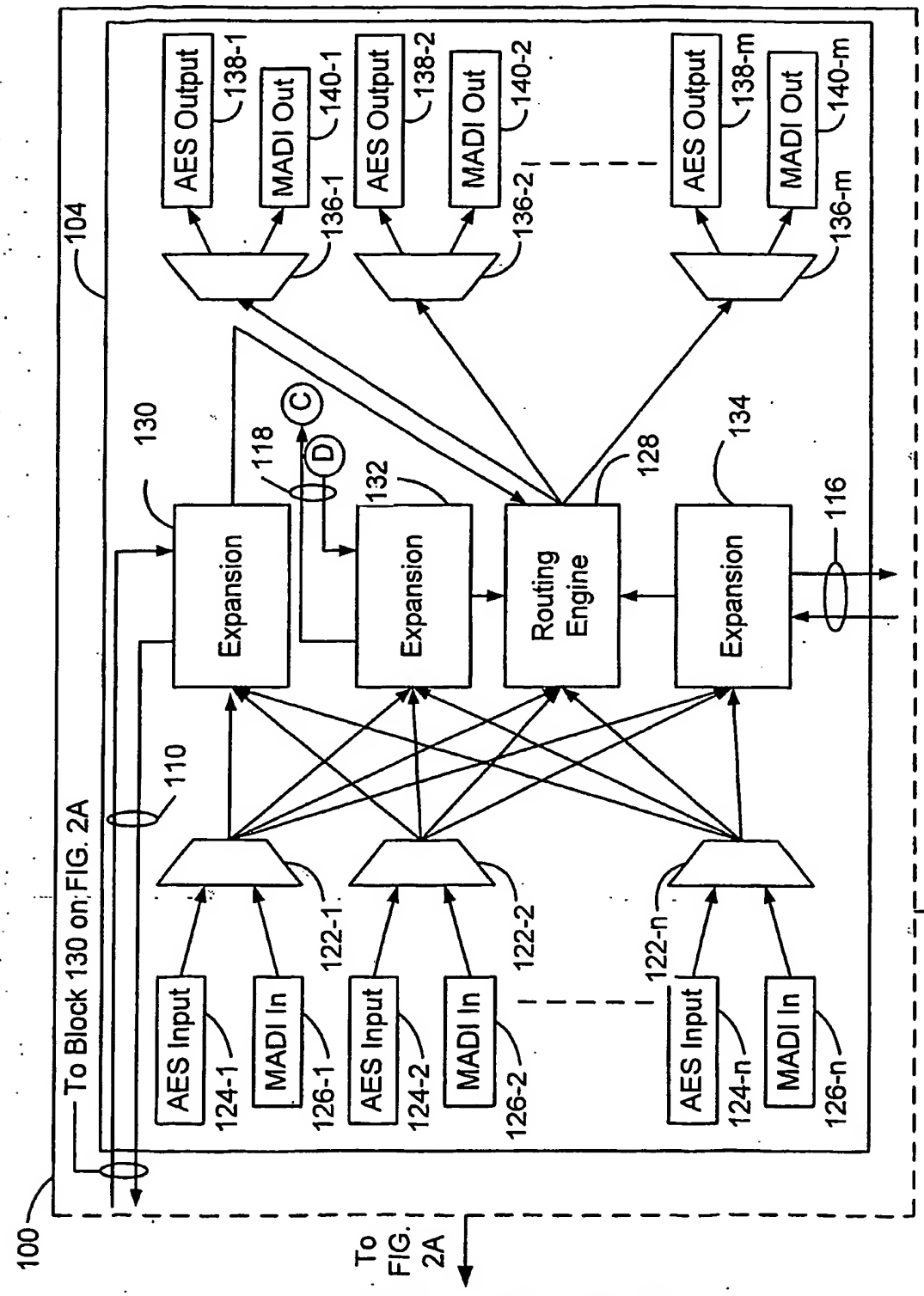
100
104
To Block 130 on FIG. 2A
To FIG. 2A
To FIG. 2D
AES Input
124-1
MADI In
126-1
122-1
AES Input
124-2
MADI In
126-2
122-2
AES Input
124-n
MADI In
126-n
122-n
110
Expansion
130
Expansion
132
Routing Engine
128
Expansion
134
116
118
C
D
AES Output
138-1
MADI Out
140-1
136-1
AES Output
138-2
MADI Out
140-2
136-2
AES Output
138-m
MADI Out
140-m
136-m

FIG. 2C

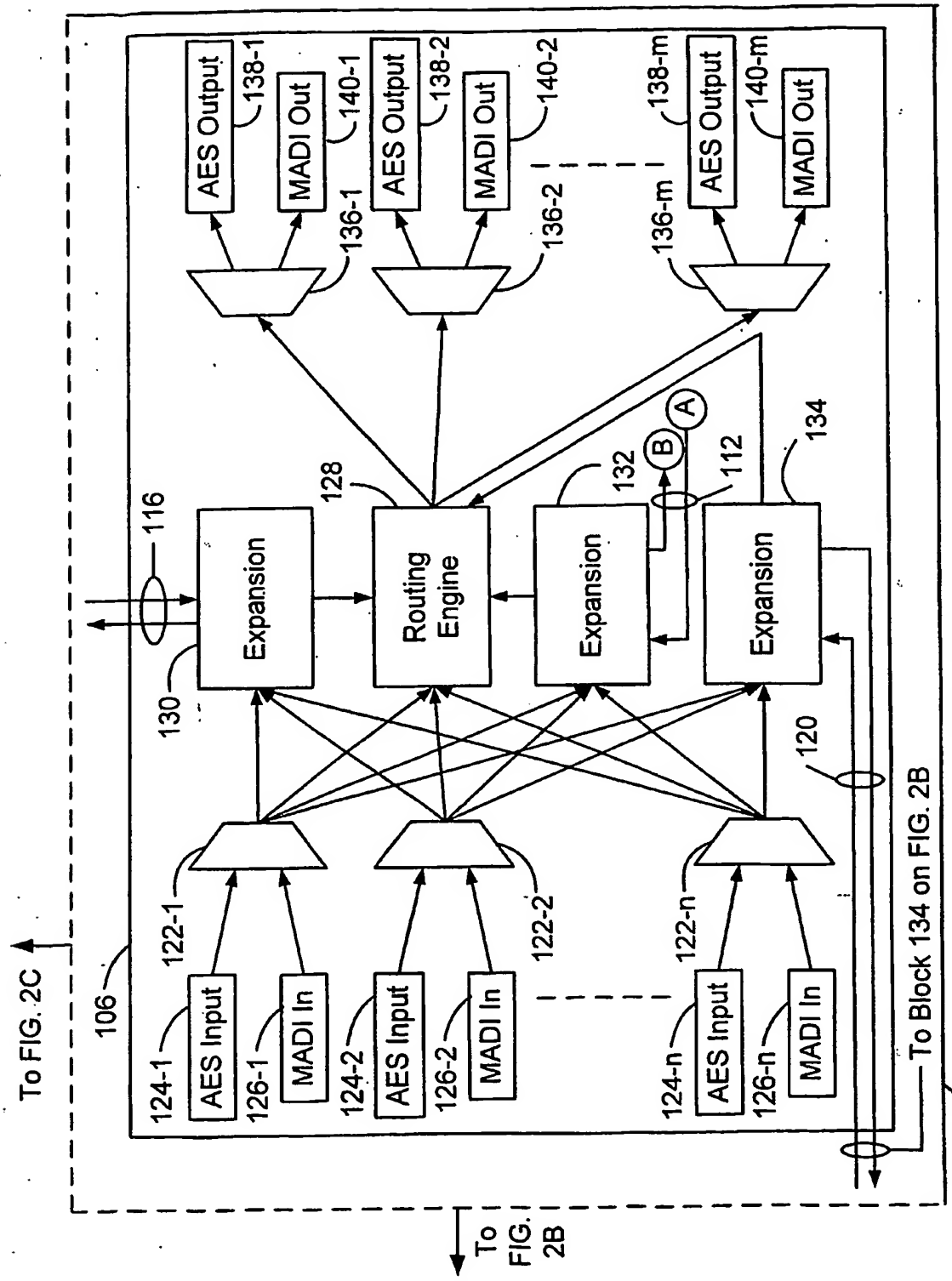
To FIG. 2C
106
124-1
AES Input
126-1
MADI In
124-2
AES Input
126-2
MADI In
124-n
AES Input
126-n
MADI In
122-1
122-2
122-n
120
130
Expansion
116
128
Routing Engine
132
Expansion
B
A
112
134
Expansion
136-1
136-2
136-m
138-1
AES Output
140-1
MADI Out
138-2
AES Output
140-2
MADI Out
138-m
AES Output
140-m
MADI Out
To Block 134 on FIG. 2B
100
To FIG. 2B

FIG. 2D

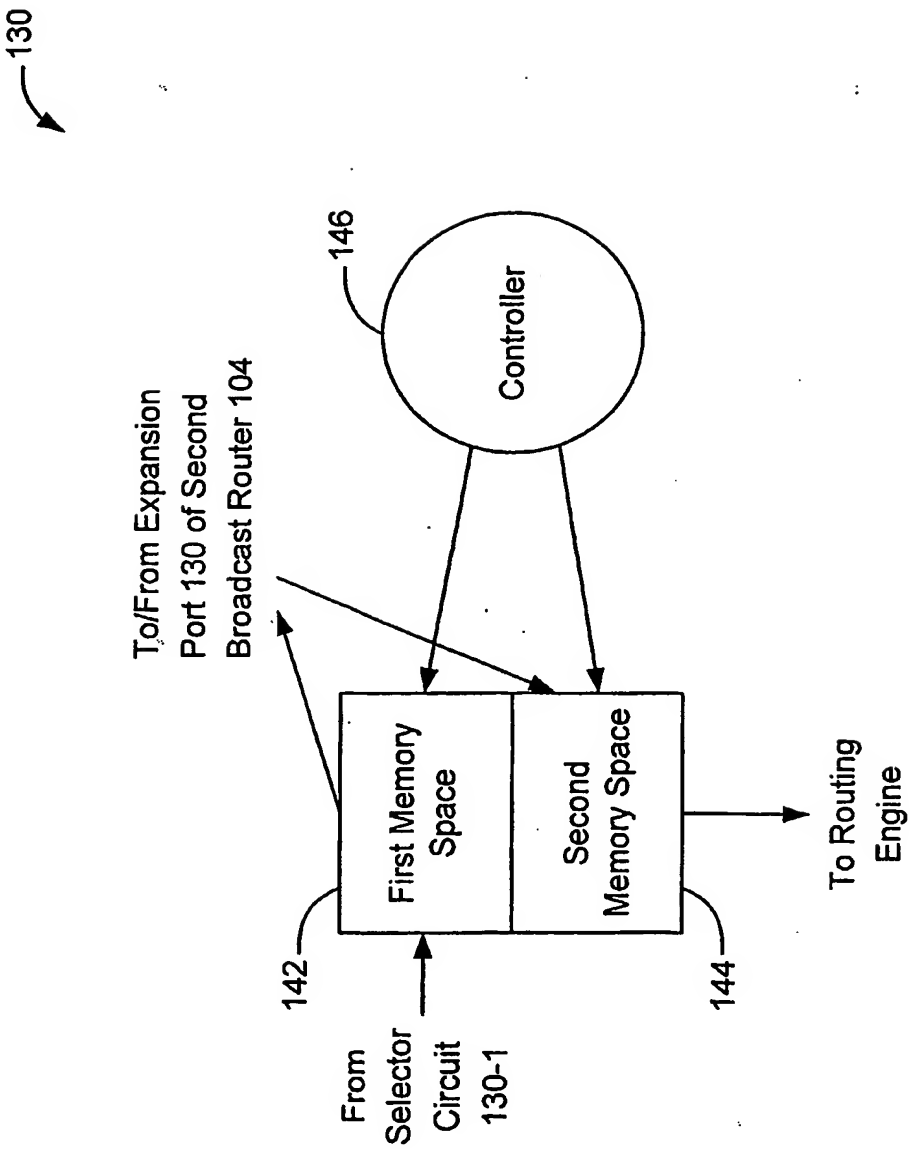
130
146
Controller
To/From Expansion Port 130 of Second Broadcast Router 104
First Memory Space
Second Memory Space
To Routing Engine
142
144
From Selector Circuit 130-1

FIG. 3

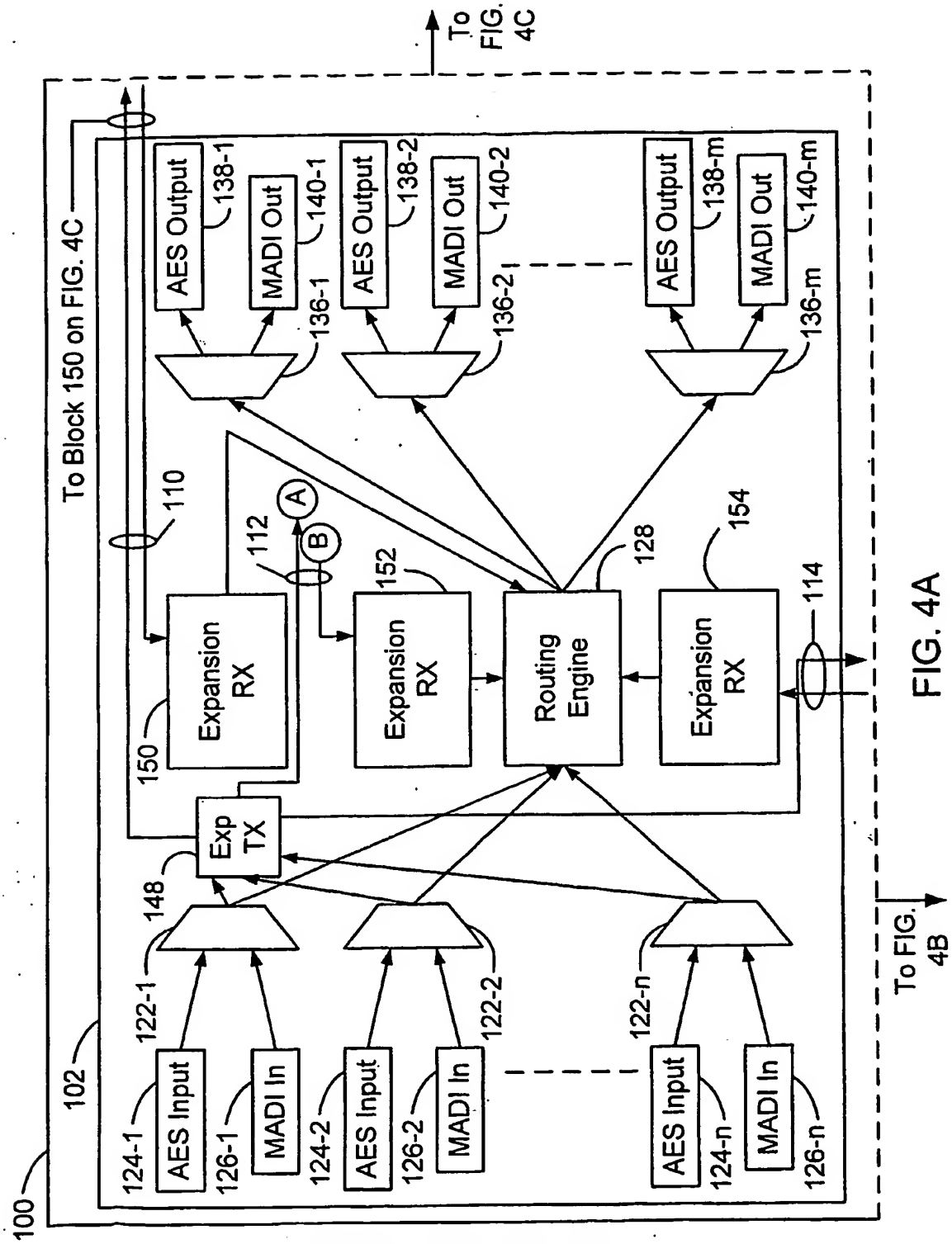
To FIG. 4C
To Block 150 on FIG. 4C
AES Output
138-1
MADI Out
140-1
136-1
AES Output
138-2
MADI Out
140-2
136-2
AES Output
138-m
MADI Out
140-m
136-m
110
112
A
B
152
128
154
114
Expansion RX
150
Expansion RX
Routing Engine
Expansion RX
Exp TX
148
122-1
122-2
122-n
AES Input
124-1
MADI In
126-1
AES Input
124-2
MADI In
126-2
AES Input
124-n
MADI In
126-n
102
100
To FIG. 4B

FIG. 4A

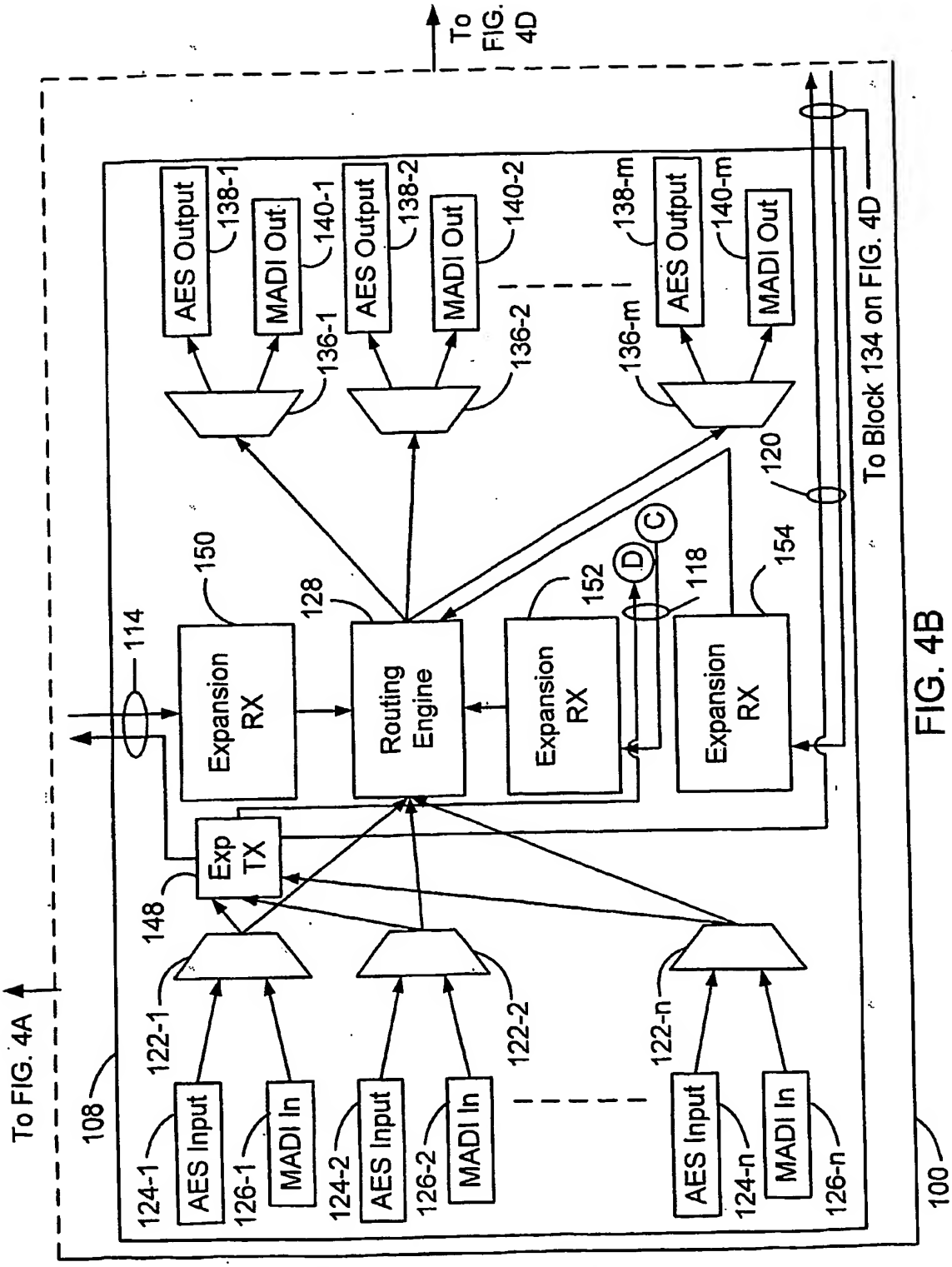
To FIG. 4D
To Block 134 on FIG. 4D
To FIG. 4A
AES Output
MADI Out
AES Input
MADI In
Expansion RX
Routing Engine
Exp TX
100
108
114
118
120
122-1
122-2
122-n
124-1
124-2
124-n
126-1
126-2
126-n
128
136-1
136-2
136-m
138-1
138-2
138-m
140-1
140-2
140-m
148
150
152
154
C
D

FIG. 4B

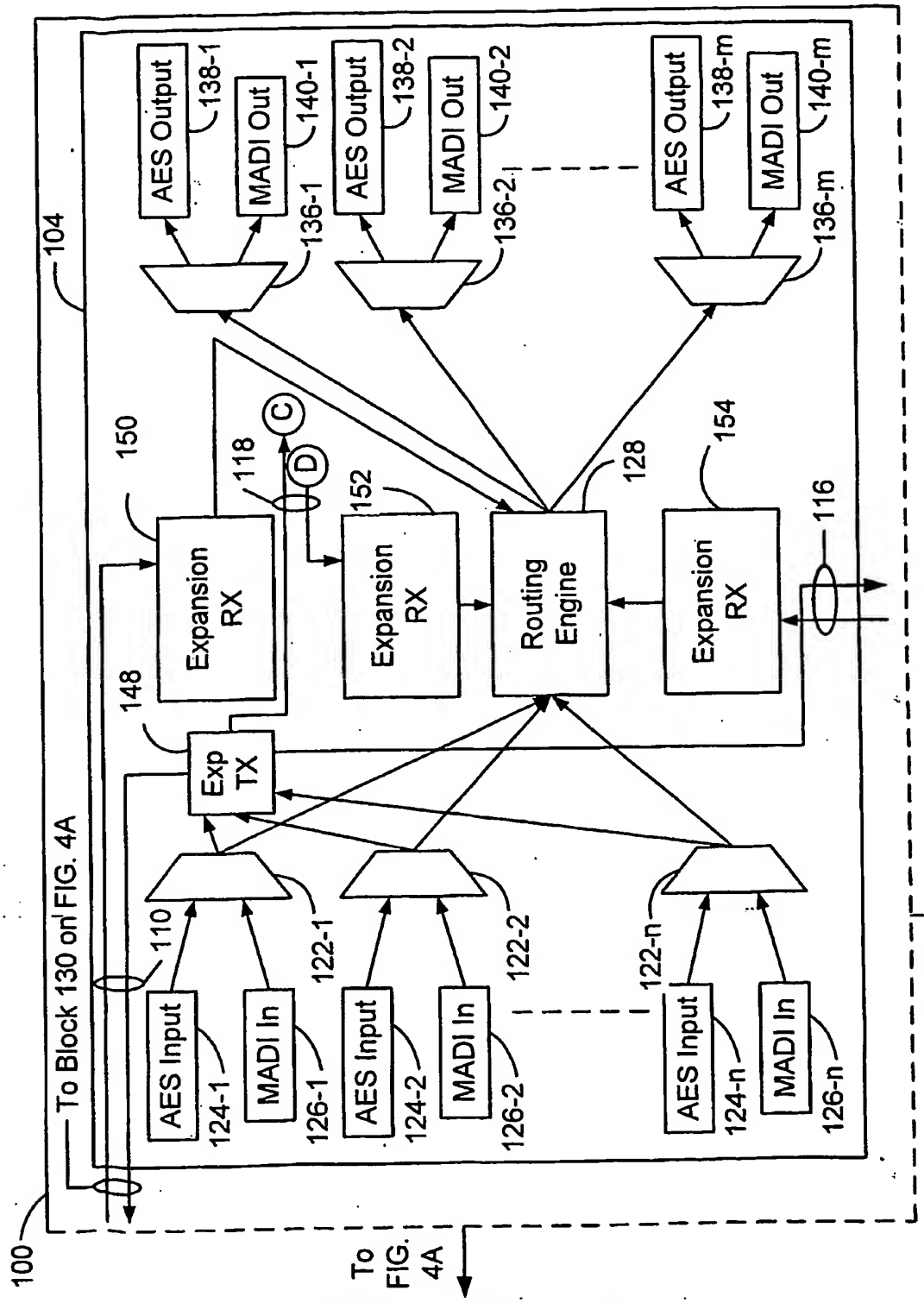
100
104
To Block 130 on FIG. 4A
To FIG. 4A
To FIG. 4D
AES Input
124-1
MADI In
126-1
110
122-1
AES Input
124-2
MADI In
126-2
122-2
AES Input
124-n
MADI In
126-n
122-n
Exp TX
148
Expansion RX
150
Expansion RX
152
Routing Engine
128
Expansion RX
154
116
118
C
D
AES Output
138-1
MADI Out
140-1
136-1
AES Output
138-2
MADI Out
140-2
136-2
AES Output
138-m
MADI Out
140-m
136-m

FIG. 4C

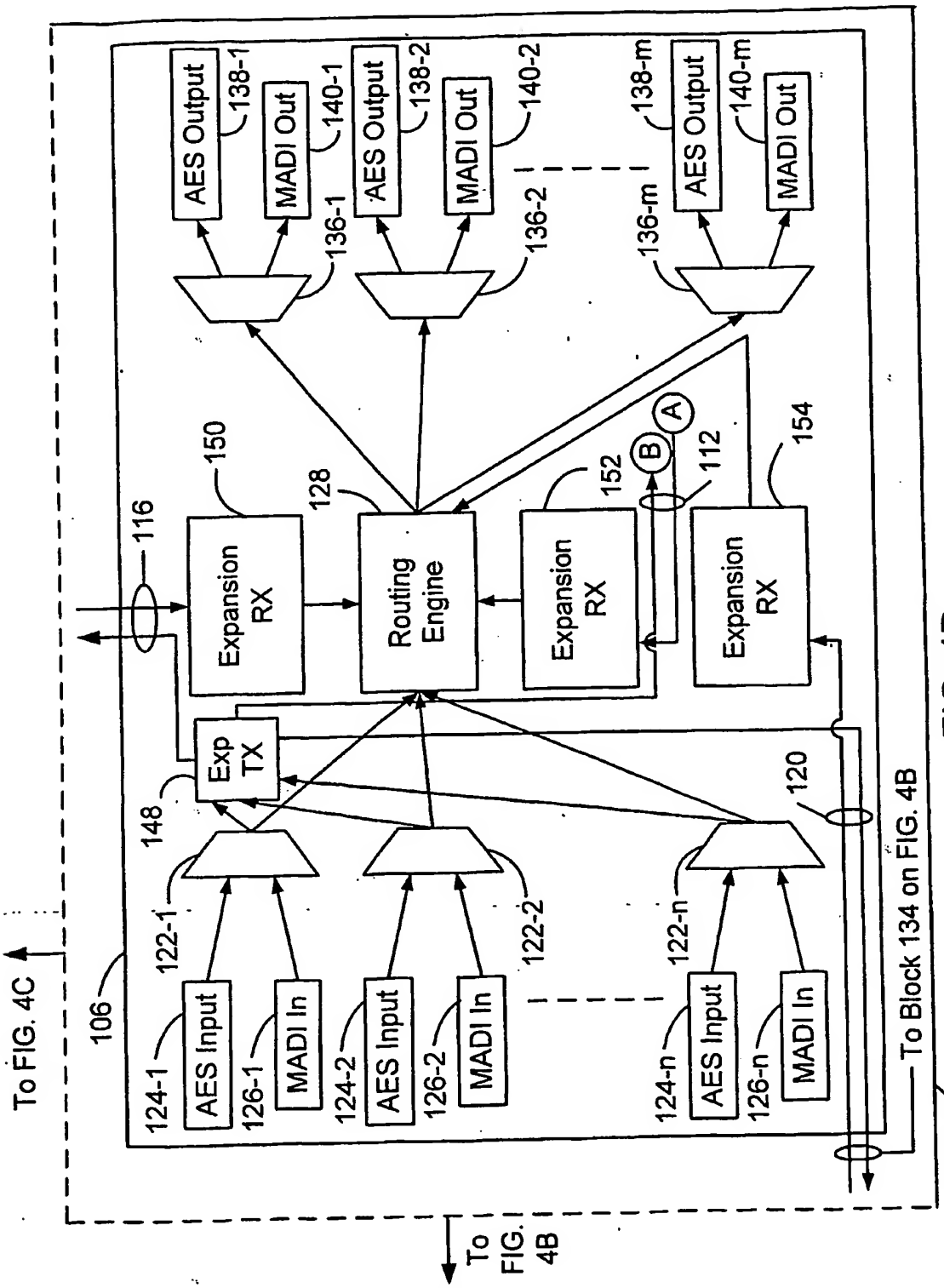
To FIG. 4C
To FIG. 4B
To Block 134 on FIG. 4B
106
100
116
112
120
148
128
150
152
154
Expansion RX
Routing Engine
Expansion RX
Expansion RX
Exp TX
A
B
AES Output
MADI Out
AES Output
MADI Out
AES Output
MADI Out
136-1
136-2
136-m
138-1
140-1
138-2
140-2
138-m
140-m
AES Input
MADI In
AES Input
MADI In
AES Input
MADI In
122-1
122-2
122-n
124-1
126-1
124-2
126-2
124-n
126-n

FIG. 4D

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US03/18848

A. CLASSIFICATION OF SUBJECT MATTER
IPC(7) : H04L 12/28, 12/56, 12/54; H04J 3/26
US CL : 370/389,401,432
According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
U.S. : 370/389,401,432

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
IEEE Database Search: (search terms) scalable router

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y, P	US 2003/0067925 A1(CHOE et al) 10 April 2003 (10.04.2003), abstract, figure 2, and sections 0037-0044.	1, 2, 10, 11
Y, P	US 6,496,510 B1(TSUKAKOSHI et al) 17 December 2002 (17.12.2002), abstract, figure 2, 11, column 1, lines 53 to column 2, lines 51.	1, 2, 10, 11
A, P	US 2002/0150093 A1(OTT et al) 17 October 2002 (17.10.2002), abstract, Figure 19.	1-11
A, P	US 2003/0021232 A1(DUPLAIX et al) 30 January 2003 (30.01.2003), figure 3.	1-11
A, P	US 2003/0099247 A1(TOUTANT et al) 29 May 2003 (29.05.2003), abstract, figures 1-6.	1-11
A	TZENG. F.N, et al. Cost-Effective Switching Fabrics with Distributed Control for Scalable Routers, University of Louisiana. IEEE 2002, entire article.	1-11

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"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

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"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
16 September 2003 (16.09.2003)	25 NOV 2003
Name and mailing address of the ISA/US Mail Stop PCT, Attn: ISA/US Commissioner for Patents P.O. Box 1450 Alexandria, Virginia 22313-1450 Facsimile No. (703)305-3230	Authorized officer Chirag Shah Telephone No. 703-305-9686

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Rec'd PCT/PTO 16 DEC 2004

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US03/18848

A. CLASSIFICATION OF SUBJECT MATTER
IPC(7) : H04L 12/28, 12/56, 12/54; H04J 3/26
US CL : 370/389,401,432
According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
U.S. : 370/389,401,432

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
IEEE Database Search: (search terms) scalable router

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y, P	US 2003/0067925 A1(CHOE et al) 10 April 2003 (10.04.2003), abstract, figure 2, and sections 0037-0044.	1, 2 , 10, 11
Y, P	US 6,496,510 B1(TSUKAKOSHI et al) 17 December 2002 (17.12.2002), abstract, figure 2, 11, column 1, lines 53 to column 2, lines 51.	1, 2, 10, 11
A, P	US 2002/0150093 A1(OTT et al) 17 October 2002 (17.10.2002), abstract, Figure 19.	1-11
A, P	US 2003/0021232 A1(DUPLAIX et al) 30 January 2003 (30.01.2003), figure 3.	1-11
A, P	US 2003/0099247 A1(TOUTANT et al) 29 May 2003 (29.05.2003), abstract, figures 1-6.	1-11
A	TZENG. F.N, et al. Cost-Effective Switching Fabrics with Distributed Control for Scalable Routers, University of Louisiana. IEEE 2002, entire article.	1-11

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"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

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Date of the actual completion of the international search	Date of mailing of the international search report
16 September 2003 (16.09.2003)	25 NOV 2003
Name and mailing address of the ISA/US Mail Stop PCT, Attn: ISA/US Commissioner for Patents P.O. Box 1450 Alexandria, Virginia 22313-1450 Facsimile No. (703)305-3230	Authorized officer Chirag Shah Telephone No. 703-305-9686

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